AMRL-TDR-64-38

DEVELOPMENT OF FOOD ITEMS TO MEET AIR FORCE REQUIREMENTS FOR SPACE TRAVEL

TECHNICAL DOCUMENTARY REPORT No. AMRL-TDR-64-38

JUNE 1964

BIOMEDICAL LABORATORY
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AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Contract Monitor: E. W. Speckmann, 1st Lt, USAF
Project No. 7164, Task No. 716405

(Prepared under MIPR No. 33(616)61-18 by
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700 - August 1964 - 448-2-30

FOREWORD

This report was initiated by the Biomedical Laboratory, 6570th Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. The original research and development work was accomplished by the Armed Forces Food and Container Institute under Military Interdepartmental Purchase Request No. 33(616) 61-18, Task No. 40491, "Development of Food Items to Meet Air Force Requirements for Space Travel." This work represents development of food and container items for high altitude and for space feeding. The work was performed in support of Project No. 7164, "Biomedical Criteria for Aerospace Flight," and Task No. 716405, "Aerospace Nutrition." A number of investigators in both the Food Division and the Container Division contributed to the development effort: SP-7 Eugene Schertz, Mary Klicka, Louis Jokay, Justin Tuomy, Dr. Karl Johnson, Horace Cosler, Albin Slakis, Hilda Clayton, Yoshito Masuoka, Frank Rubinate, Gendron Legris, and Robert Matthern.

ABSTRACT

Prototype foods to meet the requirements of space travelers have been investigated. These foods were required to be lightweight, easy to prepare, highly nutritious, neither thirst provoking nor gas forming, and low in crude fiber. The food should not exceed a cube size of 1/4 - 3/8 inch and should, after storage up to 6 months at 40, 70, and 100°F,closely resemble the color, flavor, and texture of fresh food. All foods were rated on a 9.0 Hedonic scale. Foods served to a panel at the Armed Forces Food and Container Institute were considered acceptable when they rated 6.0 or above. Freeze-dehydrated foods were investigated. Certain tubed foods were studied to determine whether they were acceptable after storage up to 15 months at 40, 70, and 100°F. Many tubes showed internal swelling. Peaches, apricots, beef and vegetables, and beef and gravy in tubes with Sunex 11-S lining were found to be acceptable in both texture and taste. Studies of Chlorella 71105 were made to modify the flavor, taste, and color and to enhance the nutritive values. Two strong objections to the use of this algae were its dark green color and its bitter gagging aftertaste. Three processes were developed to remove the bitter taste of the algae. However, further studies should be completed to identify the bitter taste.

PUBLICATION REVIEW

This technical documentary report is approved.

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INTRODUCTION

With the advent of the space age, we are faced with the complex problem of developing and producing foods which will meet the needs of space travelers. Experience from the space flights to date shows that foods required should be lightweight, easy to prepare, highly nutritious, low in crude fiber, and closely resemble the color, flavor, and texture of freshly prepared foods. Since storage space and weight are critical problems in space craft, dehydrated foods, bite-size foods of high caloric density, and certain semi-solid tubed foods have been investigated.

Careful deliberation of the requirements of the space traveler confined under such exacting conditions, for preparation and consuming foods, led to the study of various methods of food processing.

DEHYDRATED FOODS

The continuous advance in freeze-drying techniques has reached a point where a wide variety of dehydrated foods is available. These include beverages, fruits, fruit juices, cereals, desserts, meats, meat combination items, soups, vegetables, and vegetable combination items.

The foods to be consumed while hot have to reconstitute within 15 minutes in water not exceeding 165° F. Other items need to rehydrate completely in water at the ambient temperature of the space capsule. All food was prepared in such a manner that after reconstitution none of the individual pieces would exceed a cube size of 1/4- to 3/8-inch. This particle size enabled the food to pass through the opening in the feeding nozzle on containers furnished by the Air Force. All the newly prepared foods were made from ingredients that contained the highest possible caloric values, and were neither thirst provoking nor gas forming.

Prototype food was served to a panel at the Armed Forces Food and Container Institute. Each prototype food was rated on a 9.0 Hedonic scale. A rating of 6.0 or above was considered acceptable.

Table I lists all the foods supplied for simulator and monotony studies and the Hedonic scale acceptability of these items after storage at 40, 70, and 100° F. The serving size and reconstitution ratios are listed in Table II.

As the first approach to developing freeze-dehydrated foods, commercial junior baby foods (meats, fruits, puddings) were used. Some of the freeze-dehydrated baby foods rehydrated satisfactorily only when the product was ground to a powdery consistency after dehydration. Although pulverization facilitated the rate of rehydration, the smooth paste-like texture was found undesirable in all products. Commercial meat flavored, junior-type baby food items lost most of their meaty flavor and some became bitter. Dehydrated, pulverized vanilla custard pudding rehydrated to a thin paste and its high starch content caused some bitter flavor and mealy texture. Fruit items, especially peaches and pears, were the most promising as they retained the most natural flavor and rehydrated more readily.

Meat Products

Since the baby food items were generally not acceptable, another approach was tried using various precooked dehydrated foods such as beef cubes, peas, potatoes, chicken pieces, and dry gravy mixes. The components were blended dry in proportion to give beef stew, chicken stew, or other such combination items. It was found that after being placed in containers, the various components separated into layers when the containers were shaken. Also, rehydration of the loosely packed components was impossible without mechanical agitation or kneading in the case of flexibly packaged products. Therefore, these products did not meet AF requirements.*

Two previously developed freeze-dehydrated items (scrambled eggs and meat balls with gravy) were found acceptable after some minor formulation and processing changes. Freeze dehydrated scrambled eggs were produced as outlined in U. S. Patent 3,009,818. After cooking, the eggs were molded into a wafer form which would fit into standard 202 x 311 cans.

Meat balls 1/4-inch in diameter were prepared in accordance with LP/P DES C-107-59 with the following modifications: (1) spices were kept to a minimum level; (2) one to two per cent yellow corn meal was added to the basic mix to improve texture and rehydration time; (3) meat balls were deep fat fried at 350° F. for 45 seconds, frozen, and freeze dehydrated; (4) meat balls were packaged for serving with an onion-free gravy mix.

Finally an approach was developed for other meat products that rehydrated in 165° F. water without agitation. Each component was precooked and diced to the required 1/4- to 3/8-inch cube size. Suitable gravy or sauce was prepared separately and combined with the diced components to get the desired texture. The combination items were frozen in cylindrical rolls then sliced into 1/2-inch thick discs. Moisture was removed by freeze

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* See Appendix.

dehydration under not more than 750 mm Hg absolute pressure and 110 to 125° F. platen temperature. The dehydrated discs represented a uniform mixture of all ingredients that generally rehydrated without much mechanical agitation in 165° F. water within 15 minutes when stacked two to three inches deep in 202 x 311 cans. Bulk of these dehydrated foods was greatly decreased over those previously investigated. Descriptions of the processing of specific products using this method are given below.

Beef was prepared in a similar manner for beef pot roast, beef w/vegetables, beef w/gravy, swiss steak, and beef w/mushroom gravy. Boneless beef top rounds which were used in the fresh chilled state were trimmed of all fat, connective tissue, and semi-membraneous materials. The trimmed rounds were cut along muscle junctures and then stuffed into spring loaded round molds. The meat was processed in the molds in a retort for 1-1/2 hours including 15 minutes up time at 10 pounds pressure, 240° F. During processing, the molds were placed on trays to catch meat drippings. After cooking, the meat was chilled overnight under constant spring pressure in the mold. Chilled, cooked meat rolls were sliced in 1/4-inch thick slices and diced into 1/4-inch cubes. Chilled beef drippings (broth) was filtered to remove hardened beef fat.

Dry gravy mixes which contained as few gas producing components as possible were formulated for use in the combination meat items. The dry gravy mixes were rehydrated with diluted beef broth prior to blending with meat cubes. When vegetables such as mushrooms or potatoes were used in the combination item, they were cooked, diced into 1/4-inch cubes, and added to the gravy-meat combination.

Chicken combination items were prepared from the white meat of grade A fresh chilled roasting chickens, 4 to 6 pounds dressed. Skin membrane, connective tissue, fat, and ligaments were removed. The white meat was processed in the same manner as described for beef except that the chicken broth was not saved. Chicken with gravy and chicken stew with vegetables were prepared by using diced chicken pieces, dry gravy mixes, and vegetables prepared in the same manner as those used for beef combination items.

Chicken with rice was prepared by using dehydrated discs of cubed, precooked white chicken meat that had been mixed with a chicken-flavored soup and gravy mix and instant rice. Twelve grams of instant rice were packed in alternating layers with 20 grams of chicken discs in the cans to facilitate a more uniform rate of rehydration. Instant rice and chicken-flavored soup and gravy mix conformed with specifications MIL-R-35084 and MIL-S-35022A, respectively. The chicken w/rice required 30 minutes to

rehydrate in 165° F. For this reason, investigations were made to dehydrate the rice as a component in the disc. This method was not successful.

Since fresh turkeys were not available, frozen tom turkeys (20-22 lbs.) were obtained for white turkey meat which was prepared in the same manner as chicken meat.

It is desirable to use foods of low onion content for aerospace travel. Therefore, a beef hash formulation had to be developed that would give an acceptable end-product with a low level of onion. Inside beef rounds were trimmed of fat, connective tissue, and membraneous material before being ground through a 1/2-inch plate. The ground beef was cooked in a steam kettle in its own juice until well done. The beef broth or juice was drained, chilled, and filtered to remove fat. After the cooked ground beef had been chilled overnight, it was mixed with cooked 1/4-inch cubed potatoes, hash gravy, and diluted beef broth to make an acceptable beef hash. The hash was then frozen, cut into discs and dehydrated. The potatoes rehydrated more slowly than the other components in the hash.

In order to provide as much variety as possible, veal was prepared with a barbecue sauce. Since barbecue sauce is normally quite spicy, considerable effort was expended to develop one that would be acceptable and yet keep the spice level low. Fresh veal hindquarters which did not exceed fifty pounds were boned and the fat and connective tissue removed. The trimmed meat was processed, prepared, combined with barbecue sauce and dehydrated into discs in the same manner as the beef combination.

Fish sticks had been requested; however, due to the texture of this item, it was not possible to develop an item which would pass through the feeding nozzle and retain its shape and texture. In order to provide a fish item, a fish vegetable creole was developed.

Frozen haddock was cooked in salted water. Precooked rice, diced potatoes, green peas, white sauce, and non-gas forming spices were blended with the fish under low heat, giving an acceptable combination food. The fish creole was frozen into cylinders, cut into 1/2-inch discs and freeze dehydrated.

Several approaches were investigated in an attempt to develop an acceptable bacon item. Prefried bacon was found too salty and fatty for use in aerospace feeding. This bacon was combined with cornmeal or potatoes with no success. After removing gristle, cartilage, and visible fat, low salt, medium smoked Canadian style bacon was sliced 1/8-inch thick and diced into 1/4-inch square pieces. The bacon pieces were washed

in tepid water to remove excess salt and then combined with applesauce and white sauce. The bacon item was then made into discs and freeze dehydrated as previously described. Final product rehydrated satisfactorily, but it lacked enough bacon characteristics to be acceptable.

Alimentary Paste Products

Considerable difficulties were encountered in developing items which contained alimentary paste. Commercially available noodles, macaroni, and spaghetti would not completely rehydrate at 165° F. water. Freeze dehydrated precooked alimentary pastes became excessively puffed when freeze dried and did not completely rehydrate. Commercially canned spaghetti which was freeze-dried would not completely rehydrate in 165° F. water. Commercially canned spaghetti in cheese and tomato sauce was prepared into discs and freeze-dehydrated. This combination rehydrated quite easily indicating that alimentary pastes should be prepared with a higher moisture sauce to create an adequate porous texture which would facilitate proper rehydration. However, storage studies of this product indicated that the tomato component was not stable. Thin 1/6-inch diameter noodles were soaked in cold water to remove excess soluble starch. The noodles were then cooked, cut into one-inch segments, and blended in the proportions of three parts noodles to two parts meat sauce by weight. This combination food was then frozen, made into discs, and freeze-dehydrated. The noodles in meat sauce rehydrated completely in 30 minutes with 165° F. water, but during storage, the noodle component became progressively more difficult to rehydrate. Therefore, the noodles in meat sauce was reformulated. Fresh beef round was trimmed of fat and connective tissues, ground through a 3/8-inch plate, and cooked in its own juice. The beef broth was drained from the beef and chilled to set the fat. After the fat had been removed from the broth, it was blended with the ground cooked beef and a brown gravy. Thin cooked noodles were chopped into 1/2-inch segments, washed, and blended with the meat sauce in a ratio of one part noodles to three parts meat sauce by weight. The reformulated noodles in meat sauce which had moisture content of 75% was made into discs and freeze dehydrated. This combination item rehydrated adequately initially and during storage studies.

Fruit and Vegetable Products

Previously developed dehydrated juices, fruits, and vegetables that met AF requirements were used whenever possible and in some instances slight modifications were made. Apple, orange, grape, grapefruit, and orange grapefruit blend juices were produced per LP/P DES-C-146-61, ZJ 00890, MIL-C-35096, ZJ 00822, MIL-J-35073, respectively. Grapefruit and orange grapefruit blend juices required additional 50 grams of sugar before the products were acceptable. Applesauce, peas, sweet potatoes, and lima beans were prepared per purchase documents MIL-A-35045, LP/P DES-C-151-61, LP/P DES-C-131-62, and LP/P DES-C-144-61, respectively. Salt was packaged with the vegetable items to provide adequate seasoning.

Freeze-dehydrated tomato juice was developed using a commercially canned juice. After dehydration, the dried product was crushed into a powder which rehydrated very readily. A commercial dehydrated tomato item (90% tomato product) which rehydrated satisfactorily, was also tested.

Fancy whole canned tomatoes were cut into quarters and placed into 202 x 314 cans with sufficient juice to fill the can. After freezing in the can, the frozen product was removed, sliced into 1/2-inch discs, and freeze dehydrated. Eight grams of dehydrated tomatoes plus one gram of sugar is a serving.

Mashed potatoes were prepared according to the following formula:

100 grams - dehydrated potato flakes
5 grams - salt
0.5 grams - pepper, white
8 grams - shortening
5 grams - nonfat dry milk

The ingredients were mixed in a mechanical mixer for 5 minutes and then packaged.

Idaho Russet potatoes, U. S. No. 1, were peeled, diced into 1/4-inch cubes, cooked in steam kettle, mixed with brown gravy, frozen in cylinders, sliced into 1/2-inch discs, and freeze dried to make a diced potato and gravy item. To prepare salted plain and salted parsleyed potatoes except for a few minor changes, U. S. No. 1 Idaho Russet potatoes were used. These were peeled, diced into 1/4-inch cubes, cooked in a steam kettle with enough salted water (1 oz. salt to 3 qts. water) to cover, washed in cold salted water to remove excess starch, and freeze-dried. For the parsleyed potatoes, dry parsley was added to the dehydrated product.

Commercially canned cream style corn was frozen into cylinders, sliced into 1/2-inch discs, and freeze-dehydrated to obtain an acceptable product.

Dehydrated green beans were developed by using U. S. Grade A sieve size 2 and 3 canned green beans which were cut into 1/4-inch pieces and freeze-dehydrated.

Dehydrated lima beans were produced per LP/P DES-C-144-61 using baby lima beans.

To develop dehydrated wax beans in cream sauce and green beans in cream sauce, either canned or cooked fresh green or wax beans cut into 1/4-inch pieces were used. The beans were blended with an instant white sauce frozen into cylinders, sliced into 1/2-inch discs and freeze dehydrated.

Cereal Products

Cooked cereal products developed were cooked in sufficient water so that the starch was completely gelatinized. The cooked slurry was spread on a tray which was divided into smaller sections by a removable divider which facilitated heat transfer during drying. The slurry was frozen, freeze dehydrated and then powdered in a Fitz Mill.

Dry cereal products were developed from commercial dry cereals which were either chopped, pulverized into small pieces, or powdered to give maximum surface area for rapid rehydration. The dry cereal products were combined with nonfat milk, sugar and other ingredients in the dry state prior to packaging. The ingredients reconstituted rapidly into acceptable breakfast foods.

Freeze dehydrated Spanish rice was formulated from low moisture instant rice or any other commercially available long or short grain rice which was cooked with the seasoning and other ingredients. The cooked Spanish rice was placed on a shallow tray which was divided into smaller sections by a removable divider and quick frozen. The Spanish rice was freeze dehydrated and then packaged under vacuum to prevent deterioration from oxygen.

A rice gravy dish was developed by combining broken instant (low moisture) rice, pulverized freeze dried chicken, and gravy mix. The combined ingredients were packaged in the dry state.

Seasoned noodles were developed using macaroni which was freeze dried and then broken into small pieces, freeze dehydrated cooked chicken which had been pulverized, and seasoning. The items were combined and packaged in a dry state.

Puddings

Cold water soluble starch type chocolate and butterscotch pudding previously developed (MIL-D-35033A) were used for dessert items.

Soups

Dehydrated soup mixes were developed by either modifying commercial soup mixes or soups developed for military rations.

Beef consomme was made from beef soup and gravy base (MIL-S-3271C). It reconstitutes completely in 165° F. water and can be eaten immediately after stirring. Beef and rice soup was developed using beef soup and gravy base and instant, low moisture rice (MIL-R-35084).

Chicken consomme was made from chicken-flavored soup and gravy base (MIL-S-35022A).

Chicken and rice soup was formulated from chicken-flavored soup and gravy base and low moisture rice.

Chicken and noodle soup was made by combining chicken-flavored soup and gravy base and commercial angel hair type dry noodles.

Meals on Trays

A contract study to investigate the feasibility of using precooked dehydrated foods in a fabricated tray which protected the food and contained the water for rehydration in a sealed pouch was performed by Midwest Research Institute (DA19-129-QM1645). Nine different meals, consisting of three courses (a meat, a vegetable and a dessert) were developed. The trays were hydroformed from 0.012 inch dead soft aluminum, by 80 pounds of water pressure with the edges held down by a pressure of 6-7 tons. The food components were added to the trays along with a premeasured amount of water sealed in mylar-foil-polyvinyl acetate laminate. The tray cover was then hermetically sealed to prevent deterioration of the foods. An electrical heating device for preparation of the meals was also developed. The results indicated that tray type precooked dehydrated meals with limited variety were feasible, but additional effort would be required to complete the development. Since most of the dehydrated foods developed under this project had not been storage tested, the prototype items were submitted to consumer taste panels for evaluation on a nine point hedonic scale.

Storage

The dehydrated items were stored at the constant temperatures indicated on Table I. The foods were packed in individual servings in standard 202 x 311 cans, sealed under 27 inches of vacuum. Foods which had been previously storage tested and found to be stable were not storage tested.

Foods furnished for Monotony and Simulator Studies were packed in 202 x 311 cans which had been specially designed and furnished by the Air Force and in flexible plastic tubes. The tubes were placed in 603 x 700 cans under nitrogen to provide storage protection prior to beginning of studies.

Due to the delivery schedule established for both the Monotony and Simulator Feeding studies, it was not possible to complete storage stability studies on the prototype foods prior to delivery of the foods. As Table I indicates, several components decreased in acceptability during storage tests and subsequent reformulation has resulted in more stable foods.

Previous experience has indicated that dehydrated juices should be packaged with a desiccant. Controlled humidity during packaging of these items was necessary. Therefore, all tubes were filled with dehydrated juices in a low humidity room. The filled sealed tubes were vacuum packed in 601 x 700 cans containing desiccant bags to keep the humidity low.

Informal in-house studies were conducted to evaluate the dried juices packed in tubes without desiccant. After three months' storage at 90° F. and 50% R. H., all juices began to cake, but the powder rehydrated into acceptable products when agitated.

Product descriptions based on laboratory experimental techniques were written and used for purchase of foods from commercial producers. Nutritive values for in-house and commercially produced foods are provided in Table III.

Formulations of combination foods are found in Table IV.

TUBED FOODS

Original studies of foods suitable for packaging in aluminum tubes showed that low pH products, such as applesauce, produced hydrogen swelling due to the action of the acid on the aluminum even though the tubes were lined with a commercial food grade lacquer. Storage studies were conducted to determine the possibility of using other interior coatings (Sunex 11 or Baracote) to prevent hydrogen swelling and give a more acceptable product.

The food products tested were orange juice; pineapple and grapefruit juice; grape juice; applesauce; peaches; fruit dessert; beef and vegetable.

The storage study at 100° F. indicated after one year that internal swelling occurred in many tubes.

Orange juice stored in tubes with Baracote lining had a metallic flavor, but samples in tubes with Sunex lining did not have this deficiency to a detectable quality. The storage study at 40, 70, and 100° F. was terminated after fifteen months. Both linings were considered suitable for protection of high acid foods at warehouse temperatures (40 or 70° F.) No difference was evident between either coating as far as product preservation is concerned.

Peaches, apricots, beef and vegetables, and beef and gravy were procured in tubes with Sunex 11-S lining. In-house evaluation of these products found them to be quite acceptable in both texture and flavor.

A prototype lightweight tube dispenser was developed in house for expelling tubed foods. The dispenser is shown in Figure 1.

ALGAE

Investigations on the food technology of the Sarokin strain of Chlorella, frequently referred to as Chlorella 71105, were pursued. The emphasis on these studies was placed on modifying the flavor, taste, and color of this strain of algae so as to enhance the nutritive value of

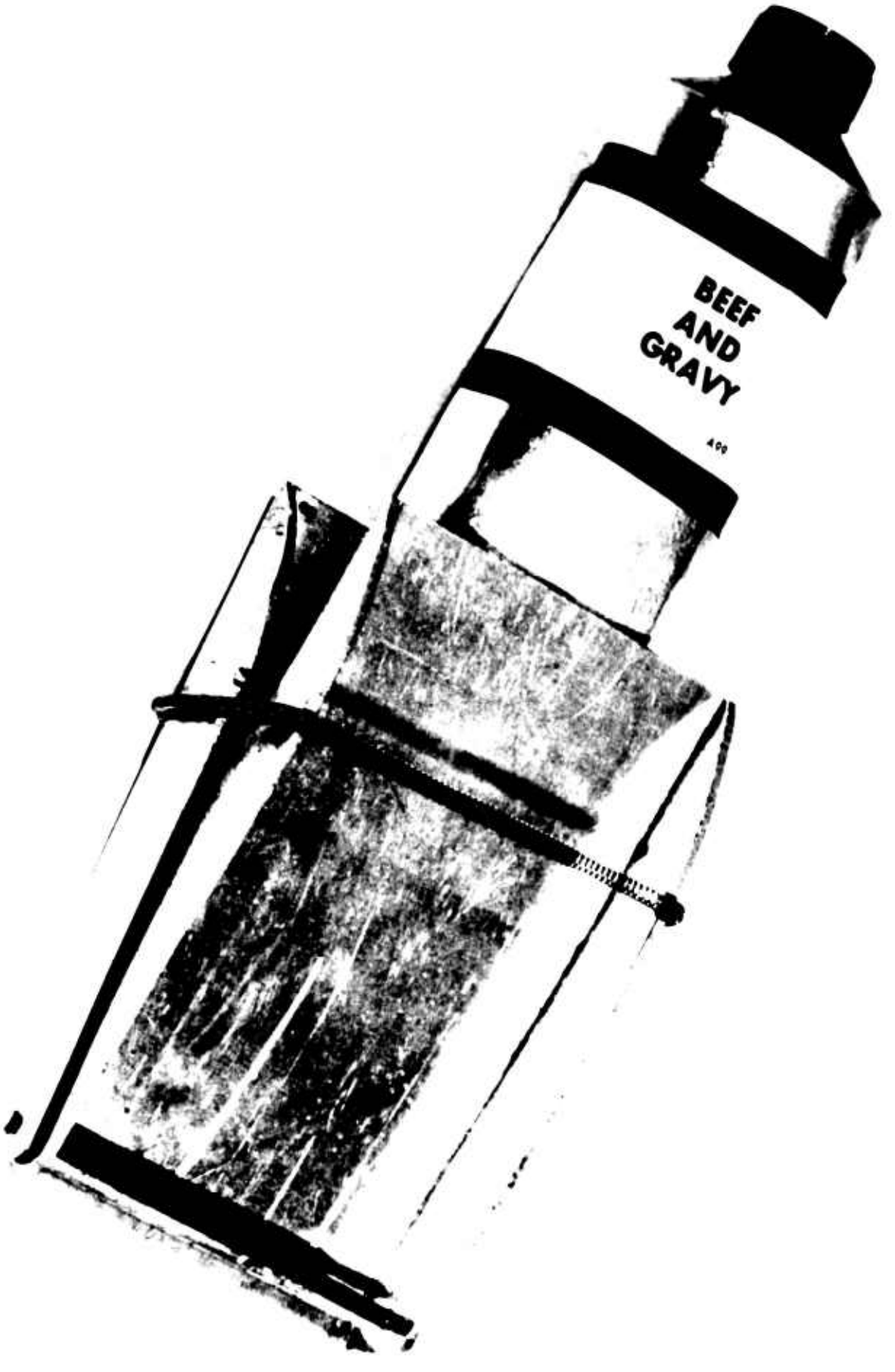

Figure 1. TUBED FOOD DISPENSER

precooked, dehydrated foods, beverages, and other foods. The algae were cultured in defined media and were harvested by centrifugation. Processing methods were developed to remove color and undesirable bitter substances. Although three processes were developed to remove the bitter principle from algae, the work to isolate and identify this bitter principle has not been completed. Recipes were formulated which provide for extension of conventional foods from 10 to 100 per cent on a weight basis.

Culture

A pure strain of algae, Chlorella 71105, has been grown in a photosynthetic process in continuous and batch systems in defined media. In the continuous, steady state, completely mixed and high intensity light system, a maximum yield of 36 g/day was attained at a nutrient feed rate of 170 ml/hour under 52,000 lumens of light. Gas, 10% carbon dioxide and 90% air by volume, at a flow rate of 30 liters per hour, was dispersed through 2.7 liters of culture. High speed mixing was used to obtain good gas exchange, heat transfer, synchronization of light and dark periods, and uniform dispersion of nutrients and cells.

In the batch system, 100 liters of culture were supplied with an excess of gas, approximately 10% carbon dioxide and 90% air, which was dispersed along the bottom of a glass tank. During the early stages of the work, mixing was obtained by recycling the algal suspension using a centrifugal pump. Later, this dispersion system was replaced by a motor-driven turbine impeller mixer placed directly in the culture. Twenty-eight fluorescent tubes, fourteen on each side of the tank, served as the source of illumination. The clear distance between the one-half inch plate glass sides of the tank was four inches. Yields up to forty-five grams per day were attained in this system when using five gram seed cultures. All algal quantities are expressed on a dry weight basis.

The defined media used contained only two organic substances, EDTA as a chelating agent and urea as the sole source of nitrogen. The T-4 medium, Table V, was used for the batch system. The T-6 medium, Table VI, was used for the feed nutrient to the continuous culture system.

Debittering and decolorizing processes

Two strong objections have been made to the use of algae as food -- its dark green color and its bitter gagging aftertaste. As the color of the food would not render it unacceptable while the bitter aftertaste would, emphasis was placed on the development of processes which would remove or destroy the bitter taste.

Three methods for removal of the bitter principle have been developed: Soxhlet extraction using methanol; Soxhlet extraction using ethanol; and preparation of a roux using butter or corn oil. The ethanol Soxhlet extraction and roux processes yield a product with essentially no bitterness; the methanol extracted product retains some bitterness. The methanol Soxhlet extraction process removed most of the chlorophyll; the ethanol extraction method removed approximately 50%; the roux retained all its color.

For the methanol Soxhlet extraction process, the harvested algae were washed to remove residual nutrients, then a quantity of algae equivalent to 39 - 40 gms dry solids was blended in a Waring Blender in 200 ml of methanol for 30 seconds. The heat evolved by blending in excess of one minute appeared to fix pigment and produce a brownish discoloration that could not be extracted by methanol. The methanol suspension of algae was poured into a single-strength cellulose extraction thimble 60 mm x 180 mm. The thimble was transferred to a Soxhlet, and the Soxhlet was fitted to a three-liter boiling flask containing 1.3 liter of methanol. The methanol was distilled at the rate of 2.5 liters per hour. The Soxhlet cycle time averaged three minutes with the withdrawal of 125 ml of extract at the end of the cycle. Soxhlet extraction required one hour for effective removal of the bitter principle.

The problem of solvent channeling was solved by continuous stirring of the methanol suspension during the extraction period. A glass stirring rod with attached propeller was extended through the Soxhlet condenser into the extraction thimble. The stirring was accomplished at 200 to 400 rpm with the result that the algae were kept in suspension except for a layer of solids on the sides of the thimble. It was observed that rate of stirring influenced the rate of extraction. When stirring at 100 rpm, five hours were required for complete extraction of color, while only 2-1/2 hours were required at 200 rpm.

Following extraction, the suspension was filtered. The methanol extracted algae had a noticeable green color. In an attempt to remove the last traces of green color, the extracted algae were suspended in a three per cent hydrogen peroxide solution. At room temperature, a more complete decolorization was effected in 18 hours. The bleaching time was reduced to five hours when a five per cent hydrogen peroxide solution was used. The white product, obtained after centrifugation and washing with distilled water, was freeze-dehydrated to remove residual solvents.

The equipment set up for extraction procedure, and final washing prior to freeze-dehydrating used for ethanol extraction of the bitter principle were essentially the same as they were for the methanol Soxhlet extraction process. Twenty to twenty-one grams, dry weight basis, of algae were suspended in ethanol. This represents about half the quantity used in the methanol extraction. The size of the original sample was reduced for ethanol

extraction to compensate for a slower filtration rate through the thimble. In another attempt to isolate and identify the source of the bitter principle of algae, samples up to 40 grams were processed for one hour. The quality of the dried algal residue was equivalent to that previously treated using only 20 grams. The ethanol was distilled at a rate of 1.8 liters per hour.

Methanol extraction removed about 12 grams of solids or 31 per cent of the total dry weight of the raw algae (Table VII). The methanol extracted chlorophyll fraction weighed 2.29 grams, while 2.04 were ether-soluble fats. The remaining 7.7 gms. were not identified. An additional 6% loss (2 gms.) was experienced in methanol extracted algae which were bleached with hydrogen peroxide.

Color measurements were made to determine the relative effectiveness of the decolorization. Light reflectance measurements were made with a Color Eye tristimulus colorimeter using a white vitrolite standard calibrated against magnesium oxide (Table VII). The tristimulus Y values indicate the relative effect of color removal and reflect the relative removal of chlorophyll. The higher the Y value, the whiter the product. The raw freeze-dehydrated algae had a deep green color. The ethanol extracted algae were light green. The methanol extracted algae had a noticeable green color; while the methanol extracted algae treated with 3% hydrogen peroxide were pure white, comparable to dried skim milk. The x and y values and the Munsell color notation are shown in Table VII, if more precise comparisons are desired by the reader.

A test panel of twenty-four persons sampled raw algae, methanol extracted algae treated with 3% hydrogen peroxide, and ethanol extracted algae processed for one, two, four, six, eighteen and twenty-four hours. The raw algae were most bitter, and the methanol extracted algae significantly more bitter than ethanol extracted. The extraction with ethanol for periods in excess of one hour did not significantly result in additional reduction of bitterness. The relative insignificance of the residual bitterness in the methanol extracted algae was shown by the results of an eleven-man technological taste panel that ate an algae-potato mixture prepared as mashed potatoes. Methanol extracted algae, which had been dried in a vacuum oven, were substituted for dried potato in 0, 25, 50, 75, and 100 percentages. The 50% substitution was graded as being acceptable with respect to texture, color and flavor.

A protein and amino acid analysis on raw, methanol extracted, methanol extracted bleached with hydrogen peroxide, and ethanol extracted algae were made to determine the effects of the various treatments. The results of this analysis are presented in Table VIII. From the amino acid analysis, it appears that the various processing methods have no significant effect

upon proportion of amino acids. The apparent increase in total protein is due to the reduction in fats and other methanol and ethanol soluble materials list in processing.

The destruction or volatilization of the bitter principle was also accomplished by preparing a roux of algae in butter. Salted butter mixed with raw unwashed harvested algae in ratios of 1 : 2 and 1 : 4 (gm butter : gm algae dry weight basis). Each mixture was heated in a 250 ml beaker, stirring continuously. Both samples were tasted every minute after boiling commenced and left a strong bitter aftertaste which persisted up to 4 minutes of boiling. The five-minute samples had a very definite reduction in bitter aftertaste. At six minutes the bitter aftertaste was gone. The flavor that persisted for treatment up to and beyond six minutes was described by various individuals as similar to that of shrimp, squash, nuts, or spinach. It was found that preparing large volumes for food preparations required much longer time for debittering. The required time appeared to be a function of the active boiling period which was dependent upon the effectiveness of stirring and heat transfer through the algal paste. Whether the loss of the bitterness was due to destruction of the bitter principle by heat, volatilization, or a chemical reaction with the butter is not known. However, strong unpleasant odors were observed while preparing a roux of the algae.

In an experiment substituting corn oil for butter ratios (oil:algae) of 1 : 2, 1 : 4, and 1 : 6 were chosen. The 1 : 2 and 1 : 4 ratios yielded acceptable products, whereas the 1 : 6 ratio did not. The quantity of corn oil was held at 4 gms for all ratios. Twelve to fifteen minutes were required to debitter the algae using corn oil.

The product processed by the roux method may be considered equivalent to raw algae (Table VII), with respect to color and loss of product when compared to that extracted by methanol and ethanol. The final product, using the roux method, is equivalent in flavor, or better, than the ethanol extracted product. The roux method requires far less equipment, time, and effort; and in addition, ordinary cooking equipment and methods are suitable. Only edible products are used and no special distillation or drying equipment is required. This method requires only six to ten minutes of active boiling as compared to the ethanol or methanol extraction process which requires an hour.

The relative advantages and disadvantages of the three processes for removal of the bitter principle from algae are summarized in Table IX.

Food Extension

Several recipes for algae were formulated to demonstrate the feasibility of using algae as a food extender. Eight of these recipes, Table X, were chosen to demonstrate the versatility of algae as a food. The soups, mashed potatoes, beefburger, fruit bar, and cocoa beverage would comprise a prototype meal. Both butter and corn oil roux make acceptable spreads for bread and crackers.

Algae debittered by any of the three processes may be used in the recipes. The quantity of algae is expressed on a dry weight basis which is approximately three-tenths the wet weight. However, algae debittered by the roux method have been used extensively in recipe formulations because of the simplicity, speed and effectiveness. Emphasis was placed on the use of the freeze-dehydrated and dried foods because of their possible use in closed ecological systems.

In making up the recipes, various ingredients were used. The mashed potato was prepared using methanol extracted algae. The fruit bar recipe was varied using various combinations of dried fruit. The recipe described in the Table was the tastiest of the four. The pancakes were only fair. When raw algae were used instead of a prepared roux, the pancakes were inedible. For some reason, the pancake recipe brought out the bitterness of raw algae more than any other recipe tested. An oatmeal recipe containing less algae and substituting 100-hour shortening for corn oil was prepared.

Isolation of Bitter Principle

Three successful processes were developed to remove or destroy the bitter principle associated with the algae. However, the specific substance or substances responsible for the bitterness are not as yet known. (The term bitter principle will be used generally to include one or more bitter substances.) If the source and identification of the bitter principle were known, then a more rational approach could be applied toward its elimination. With this objective in view, work was initiated to isolate and identify the bitter principle.

To reaffirm that the loss of bitterness was not a heat labile reaction, frozen raw algae were boiled in water at atmospheric and fifteen pound gauge pressures. The bitter principle was not destroyed. Small amounts of algae suspended in ethanol and sealed in glass tubes were placed in a boiling water bath for varying periods of time.

All samples were found to retain their bitterness. The algae treated by the ethanol Soxhlet extraction method were found to be non-bitter. Consequently, a concentrate of the bitter principle was expected in the ethanol fraction. The residue resulting from the evaporation of a freshly prepared ethanol fraction was not bitter. When this fraction was allowed to stand for a month under refrigeration and then evaporated, the residue was very bitter. This resulting bitter residue was disolved in water and ether. Fractions of this bitter residue were not bitter. Attempts to determine if the bitterness were due to long chain unsaturated fatty acids (reportedly found in Chlorella) which might be soluble in or react with the ethanol were unfruitful.

Chloroform, used in place of ethanol in the Soxhlet extraction, proved to remove much more of the bitter principle than the ethanol as measured by the intensity of bitterness in the residue from the evaporated liquid fraction. Evaporation of the extract left a light yellow greasy layer which was very bitter in taste. A green colored layer also was removed which had a strong, greasy taste objectionable to some testers and easily tolerated by others. This approach appears most promising to date.

The bitter principle was also removed by frying the algae in salted butter for several minutes. Algae cooked in salted butter alone for six minutes with constant stirring gave a gritty, salty sensation in the mouth. Since salt was the predominant flavor, algae were cooked in unsalted butter. The loss of bitterness was not as apparent as when the salted butter was used. Algae were cooked with salt alone with no noticeable effect. Fresh algae when cooked plain showed no noticeable loss of bitterness.

Ether extractions of the unsalted and salted butter treated algae and the organic layer evaporated to dryness under mild conditions. The resulting fat residue had only a greasy taste. There was no off-taste in the residue from the unsalted sample and only a salty taste from the salted sample. The salt layer apparently retains some bitterness which is masked when salted butter is used. This masking effect was not apparent in unsalted butter.

The possibility of the presence of alkaloids has been considered. A search of the literature showed that an alkaloid of the pteridine family had been isolated from the blue green algae. Using methods found in the literature, an attempt was made to isolate pteridines from the particular strain of algae being used in this research.

Extractions of algae were made using sulfuric acid, hydrochloric acid, and water with minute amounts of hydrochloric acid. The two acid extracts were made on the wet algae mostly by following the general outline for amine extraction in "The Characterization of Organic Compounds," by Samuel M. McElvain. The extract was made basic with 20% sodium hydroxide and distilled. The water soluble and insoluble amines were separated from the distillate and reactions observed under ultraviolet light (UV). The water soluble amines gave a positive test in U. V. which is indicative of pteridines. The water insoluble amines also resulted in a U.V. fluorescent spot which was present only in the residue after evaporation. Other U. V. positive spots were found in the methylene chloride extract of the sulfuric acid super. Nearly identical results were obtained using 5% hydrochloric acid to extract alkaloids from the algae. Fluorescent spots were found in the water insoluble amine fraction, the water soluble amine fraction, and the alkaloid fraction.

Further studies on the specific alkaloids of interest were then made following the methods of Forrest (Archives of Biochem. & Biophysics, 1958). Both wet and dry algae were suspended in water with the solutions made very slightly acidic using hydrochloric acid (1200 ml HOH, 3ml 6N HCl). The extractions were allowed to continue for 2 weeks to remove all pteridines. The two solutions were then run through celite columns and charcoal to remove excess green color. Elution of the fluorescent material on the charcoal was accomplished by 1% ammonium hydroxide. Similar procedures were carried out with the dry algae. The charcoal eluates were acidified and placed on a Filtrol column for further fractionation. Twenty per cent aqueous acetone was used to elute the material from the column.

A summary of the various approaches attempted to isolate and identify the bitter principle are shown in chart form in Figure 2.

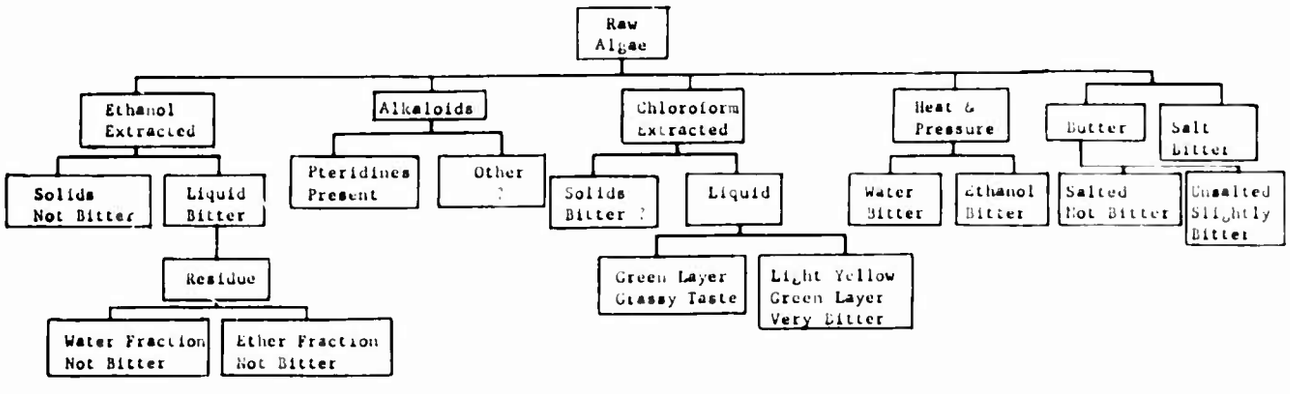

Figure 2 CHART OF APPROACH TO ISOLATION AND IDENTIFICATION OF BITTER PRINCIPLE IN ALGAE

Table I

SUMMARY OF PREFERENCE DATA FOR DEHYDRATED FOOD ITEMS

Item	Preference Rating*				
Cereal Products	Initial	40 F 3 mo	40 F 6 mo	100 F 3 mo	100 F 6 mo
All Star	6.54		6.44		4.97
Corn Chex	6.90		6.22		4.19
Frosty O	6.23		7.03		6.86
Sugar Frosted Flakes	6.15		6.50		6.28
Cream of Rice	4.51	4.36	3.86	4.61	3.50
Oatmeal	4.89	5.56	5.47	4.92	5.36
Ralston	6.18	6.61	5.75	6.06	5.50
Noodles (plain)	**				
Noodles (seasoned)	6.15	6.36	5.94	5.83	5.44
Rice	**				
Rice w/gravy	5.72	6.25	5.67	5.56	5.00
Spanish Rice	4.90	5.36	4.39	5.03	4.00
Cream of Wheat	5.36	5.53	5.11	5.44	4.75

Table I (continued)

Item	Initial	40 F 1	40F 3	40 F 6	70F 3	70F 6	100F 3	100F 6 ±
Desserts								
Butterscotch Pudding			**					
Chocolate Pudding			**					
Fruits								
Applesauce			**					
Apricots		5.4	5.4	4.2	4.6	4.9	4.0	4.3
Fruit Cocktail		7.0	6.6	4.8	6.6	5.3	3.7	3.2
Peaches		6.2	6.4	6.0	6.6	5.6	5.0	4.6
Pears		5.6	5.2	5.5	5.6	6.2	5.0	4.4
Pineapple		5.6	5.0	6.1	5.4	6.6	5.6	5.5
Prunes		6.2	5.2	6.8	6.0	6.6	5.6	6.3
Fruit Juices								
Apple Juice	**							
Grape Juice	**							
Grapefruit Juice	**							
Orang Juice	**							
Orange Grapefruit Juice	**							
Orange Pineapple Juice	***							
Pineapple Juice	***							
Tomato Juice	7.5		6.4	6.8	5.6	6.1	5.0	5.6

Table I (continued)

Soups	Initial	40 F 3	40 F 6	70 F 3	70 F 6	100 F 3	100 F 6 ‡
Beef Consomme	6.2	-	-			-	-
Beef Rice	6.3	5.8	6.5			6.0	5.7
Chicken Consomme	6.1	-	-			-	-
Chicken Noodle	6.0	6.5	7.5			4.8	7.3
Chicken Rice	6.5	5.9	6.1			6.1	5.7
Cream of Mushroom	6.0	5.5	5.7			5.7	6.0
Tomato	6.0	6.5	4.5			5.7	5.5
Vegetables							
Green Beans	**						
Carrots Cream Sauce	6.6	5.7		5.2		4.7	
Cream Style Corn		5.6	7.0	7.0	5.3	5.6	6.3
Lima Beans	**						
Peas	**						
Dried Potato/Gravy		5.3	6.7	5.3	6.7	6.2	6.7
Potatoes w/parsley	5.99	4.97	4.89			4.64	4.92
Fried Potatoes	5.73	4.83	4.97			4.61	5.11
Mashed Potatoes	**						
Sweet Potatoes	**						

Table I (continued)

Items Meat & Meat Substitutes	Initial	40 F 3	40 F 6	70 F 3	70 F 6	100 F 3	100 F 6 ‡
Bacon	6.08	5.9	5.7	6.7	6.0	5.9	5.1
Beef Hash	6.10	6.2	6.3	5.5	6.3	6.1	6.0
Beef Pot Roast	6.55	6.4	6.9	6.4	6.0	6.8	6.6
Beef W/gravy	6.44	6.5	6.5	6.7	6.8	6.6	6.0
Beef W/mushrooms Gravy							
Beef W/vegetables	6.35	6.2	6.1	6.0	5.6	6.0	-
Chicken Stew W/veg.	6.2	6.1	6.4	6.4	6.4	5.2	6.0
Chicken W/gravy	7.1	6.7	5.7	7.1	6.4	6.8	5.9
Chicken W/rice	6.5	6.8	6.4	6.6	6.3	5.8	7.1
Scrambled Eggs	**						
Fish Creole	5.4	6.2	5.9	5.8	5.7	5.4	5.9
Spaghetti in tomato Sauce	6.9	7.1	4.9		5.8	5.6	5.5
Meat Balls W/gravy	7.3	5.6	6.2	6.8	6.4	6.6	7.1
Noodles W/meat sauce	6.5	6.7	4.9	5.4	5.6	5.4	5.1
Spaghetti W/meat sauce	6.8	6.7	4.9	5.8	5.6	6.0	5.1
Swiss Steak	6.4	6.9	6.9	7.6	6.8	7.1	7.1
Turkey W/gravy	6.2	6.3	5.7	6.2	6.4	5.8	6.1
Veal/barbecue sauce	7.1	5.5	5.0	5.8	5.8	5.4	5.4
Tomatoes	6.3	6.1	6.0			5.6	5.2
Wax beans/cream sauce	6.3	5.8	5.3			5.4	4.9

*Sensory Evaluation using 9 point Hedonic Scale

**No sensory evaluation conducted since item had been successfully storage tested in which the minimum storage requirements are 6 months at 100 F and 2 years at 40 F and 70 F

***Were found to be unstable at 6 months at 100 F

‡ Numbers indicate months of storage time.

TABLE II - Product Weight and Reconstitution Instructions

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	Reconstitution Instructions
SOUPS				
Beef Consomme	2.00	Add 3 oz hot water. Stir.	2.00	Add 3 oz hot water. Squeeze until mixed.
Beef Rice Soup	8.00	Add 3 oz hot water. Let stand 15 min.	8.00	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
Chicken Consomme	2.00	Add 3 oz hot water. Stir.		
Chicken Noodle Soup	6.00	Add 3 oz hot water. Stir. Let stand 15 min.	6.00	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
Chicken rice Soup	6.00	Add 3 oz hot water. Stir. Let stand 15 min.	6.00	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
Cream of Mshrom Soup	11.50	Add 3 oz hot water. Stir. Let stand 15 min.	11.50	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
Tomato Soup	11.25	Add 3 oz hot water. Stir. Let stand 15 min.	11.25	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
Vegetable Soup	10.00	Add 3 oz hot water. Stir. Let stand 15 min.	10.00	Add 3 oz hot water. Squeeze to mix. Let stand 15 min.
VEGETABLES				
Gr Beans/Cr Sauce	15.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Green Beans	7.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Carrots/Cr Sauce	28.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Cream Style Corn	25.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Lima Beans	30.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Peas	16.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		

TABLE II (continued)

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	Reconstitution Instructions
VEGETABLES				
Diced Potato/Gravy	15.50	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Potatoes w/Parsley	8.50	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Diced Potatoes	8.50	Add 3 oz hot water. Let stand 15 min. Keep hot.		
Mashed Potatoes	20.00	Add 4 oz hot water. Stir until smooth and evenly mixed.	15.00	Add 3 oz hot water. Squeeze until mixed.
Sweet Potatoes	51.75	Add 3 oz hot water. Stir until smooth and evenly mixed.		
Tomatoes	9.00	Add 3 oz hot water. Let stand 5 min. Keep hot.	9.00	Add 3 oz hot water. Let soak 15 min.
Wax Beans/Cr Sauce	15.00	Add 3 oz hot water. Let stand 15 min. Keep hot.		
CEREALS				
All Star	24.00	Add 3 oz cold water. Stir.	14.00	Add 2 oz cold water. Squeeze to wet all product.
Corn Chex	33.00	Add 3 oz. cold water. Stir.		
Frosty O's	21.00	Add 3 oz cold water. Stir.	14.00	Add 2 oz cold water. Squeeze to wet all product.
Sugar Frosted Flakes	36.75	Add 3 oz cold water. Stir.		
Cream of Rice	20.00	Add 4 oz hot water. Stir until thick.	12.70	Add 2 oz hot water. Squeeze until mixed.
Cream of Wheat	22.57	Add 3 oz hot water. Stir until thick.		
Oatmeal	22.57	Add 3 oz hot water. Stir until thick.	15.05	Add 2 oz hot water. Squeeze until mixed.

TABLE II (continued)

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	Reconstitution Instructions
CEREALS				
Ralston	22.57	Add 3 oz hot water. Stir until · thick.	15.05	Add 2 oz hot water. Squeeze until mixed.
Noodles	19.15	Add 3 oz hot water. Let stand 30 min. Stir occasionally.	16.35	Add 3 oz hot water. Heat in oven 30 min.
Rice			10.90	Add 2 oz hot water. Hold 10 min, squeezing occasionally.
Rice w/Gravy	25.20	Add 4 oz hot water. Let stand 10 min [illegible] occasionally.	12.60	Add 2 oz hot water. Hold 10 min, squeezing occasionally.
Spanish Rice	23.60	Add 4 oz hot water. Let stand 10 min. Stir occasionally.		
DESSERTS				
Butterscotch Pudding	27.00	Add 3 oz cold water. Stir well and let set 20 min.	18.00	Add 2 oz cold water. Squeeze to mix, then let set 20 min.
Chocolate Pudding	27.00	Add 3 oz cold water. Stir well and then let set 20 min.	18.00	Add 2 oz cold water. Squeeze to mix and then let set 20 min.
FRUITS				
Applesauce	18.6	Add 3 oz cold water. Stir. Let stand 10 min.	12.40	Add 2 oz cold water. Squeeze until mixed.
Apricots	23.40	Add 3 oz cold water. Let stand 15 min.	23.40	Add 3 oz cold water. Let stand 15 min.
Fruit Cocktail	14.8	Add 3 oz cold water. Let stand 10 min.	14.8	Add 3 oz cold water. Let stand 10 min.
Peaches	23.00	Add 3 oz cold water. Let stand 10 min.		
Pears	22.50	Add 3 oz cold water. Let stand 10 min.	22.50	Add 3 oz cold water. Let stand 10 min.

TABLE II (continued)

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	Reconstitution Instructions
FRUITS				
Pineapple	25.00	Add 3 oz cold water. Let stand 15 min.		
Prunes	27.00	Add 3 oz cold water. Let stand 20 min.	27.00	Add 3 oz cold water. Let stand 20 min.
FRUIT JUICES				
Apple Juice	17.3	Add 4 oz cold water. Stir until mixed.	13.00	Add 3 oz cold water. Squeeze until mixed.
Grape Juice	17.7	Add 4 oz cold water. Stir until mixed.	13.30	Add 3 oz cold water. Squeeze until mixed.
Grapefruit Juice	18.1	Add 4 oz cold water. Stir until mixed.	13.60	Add 3 oz cold water. Squeeze until mixed.
Orange Juice	14.1	Add 4 oz cold water. Stir until mixed.	10.60	Add 3 oz cold water. Squeeze until mixed.
Orange Gft. Juice	18.1	Add 4 oz cold water. Stir until mixed.		
Orange Pineapple Juice	16.5	Add 4 oz cold water. Stir until mixed.	12.40	Add 3 oz cold water. Squeeze until mixed.
Pineapple Juice	18.9	Add 4 oz cold water. Stir until mixed.	14.20	Add 3 oz cold water. Squeeze until mixed.
Tomato Juice	10.0	Add 4 oz cold water. Stir until mixed.	8.00	Add 3 oz cold water. Squeeze until mixed.
MEAT AND MEAT SUBSTITUTES				
Bacon	42.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Beef Hash	28.35	Add 3 oz hot water. Let stand 20-25 min. Keep hot.	28.35	Add 3 oz hot water. Heat in oven 20-25 min.

TABLE II (continued)

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	Reconstitution Instructions
MEAT AND MEAT SUBSTITUTES				
Beef Pot Roast	24.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Beef with Gravy	36.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Beef w/Mshrom Gravy	36.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Beef w/Vegetables	19.00	Add 3 oz hot water. Let stand 20-25 min. Keep hot.		
Chicken Stew w/Veg.	24.00	Add 3 oz hot water. Let stand 20-25 min. Keep hot.		
Chicken w/Gravy	30.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Chicken w/Rice	32.00	Add 3 oz hot water. After 5 min add 1 more oz water. Keep hot. Let stand 30 min.		
Scrambled Eggs	28.00	Add 3 oz hot water. Let stand 2-3 min. Keep hot.	28.00	Add 3 oz hot water. Heat in oven 2-3 min.
Fish Creole	31.00	Add 3 oz hot water. Let stand 30 min. Keep hot.		
Spaghetti in Tom Sau	28.30	Add 3 oz hot water. Let stand 30 min. Keep hot.		
Meat Balls w/Gravy	43.90	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Noodles w/Meat Sauce	26.00	Add 3 oz hot water. Let stand 30 min. Keep hot.		
Spaghetti w/Meat Sauce			26.00	Add 3 oz hot water. Heat in oven 30 min.
Swiss Steak	39.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		

TABLE II (continued)

Food Items	MONOTONY STUDIES (Cans Only) Total Dry Product Weight (Grams)	MONOTONY STUDIES (Cans Only) Reconstitution Instructions	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Total Dry Product Weight (Grams)	SIMULATOR STUDIES WITH COMPACT FEEDING CONSOLE (Tubes & Cans) Reconstitution Instructions
MEAT AND MEAT SUBSTITUTES				
Turkey w/Gravy	35.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		
Veal/Barbecue Sauce	43.00	Add 3 oz hot water. Let stand 10 min. Keep hot.		

TABLE III
RECORD OF NUTRIENT COMPOSITION

CEREALS IN TUBES
(per 100 gms of Product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.	NaCl gms.
Cream of Rice	6.3	378	11.0	5.5	74.8	3.1	0.8
Rice (Plain)	5.5	394	7.3	6.4	78.0	2.8	
Rice w/Gravy	5.6	365	19.8	4.8	61.1	8.7	
Spanish Rice	7.1	359	8.2	5.9	75.9	2.9	2.9
Sugar Frosted Flakes	3.3	371	10.2	0.4	82.0	4.1	
Corn Chex	2.3	382	13.6	0.5	80.5	3.2	
Frosty O	3.6	386	20.7	5.0	65.0	5.7	
All Star	2.1	386	15.0	2.1	76.4	3.6	0.7
Oatmeal	4.0	419	17.3	10.0	65.8	3.0	
Ralston	6.0	399	15.0	8.0	66.4	3.7	0.5
Cream of Wheat	4.0	419	17.3	10.0	65.8	3.0	

Table III (continued)

CEREALS IN CANS
(per 100 gms of Product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.	NaCl gms.
Cream of Rice	6.5	380	11.0	4.50	75.0	3.0	0.8
Noodles, Plain	5.5	404	12.8	6.73	72.2	2.8	
Noodles, Seasoned	4.2	397	22.5	8.40	55.9	9.1	
Rice, Plain	5.5	394	7.3	6.40	78.0	2.8	
Rice w/Gravy	5.6	365	19.8	4.80	61.1	8.7	
Spanish Rice	2.5	237	8.5	1.30	65.3	22.5	
Sugar Frosted Flakes	3.0	387	4.6	0.30	89.0	3.1	
Corn Chex	2.4	382	13.6	0.60	80.3	3.0	
Frosted O's	3.8	382	20.8	4.70	65.1	5.7	
All Star	2.1	383	15.0	2.10	77.1	3.7	
Oatmeal	4.0	416	17.3	10.2	65.6	3.0	
Ralston	5.8	399	16.0	8.00	66.5	3.9	
Cream of Wheat	4.0	416	17.3	10.2	65.6	3.0	

Table III (continued)

NUTRITIVE VALUE OF DEHYDRATED FOODS (FRUIT AND VEGETABLE PRODUCTS)
(per 100 gms of product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.
Fruits						
Applesauce, Instant	1.1	355	1.0	0.9	95.7	1.3
Apricots	1.4	339	7.1	0.6	86.1	4.8
Fruit Cocktail	1.1	358	2.5	1.5	93.7	1.2
Peaches	2.2	365	1.7	trace	94.8	1.3
Pears	1.3	350	1.8	0.9	94.2	1.8
Pineapple	1.8	357	2.0	1.8	93.2	1.2
Prunes	1.1	352	3.3	1.1	92.2	2.2
Fruit Juices						
Apple Juice	1.9	351	0.4	0.3	96.4	1.0
Grape Juice	2.3	352	1.1	trace	96.0	0.6
Grapefruit Juice	1.7	346	5.1	0.7	89.7	2.8
Orange Juice	1.5	342	5.1	0.4	89.2	3.8
Orange-Grapefruit Juice	1.0	347	5.1	0.9	89.6	3.4
Orange-Pineapple Juice	0.6	345	4.2	0.6	91.5	3.0
Pineapple Juice	0.4	352	2.9	trace	95.0	2.1
Tomato Juice	1.1	275	13.2	1.1	64.8	19.8

Table III (continued)

NUTRITIVE VALUE OF DEHYDRATED FOODS (FRUIT AND VEGETABLE PRODUCTS)
(per 100 gms of product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.
Vegetables						
Green Beans in Cream Sauce	1.8	481	13.2	25.4	50.0	9.6
Green Beans (plain)	4.2	310	18.3	1.1	70.4	5.6
Cream Style Corn	3.6	352	12.4	5.6	76.0	2.4
Lima Beans	4.0	370	22.0	1.7	69.0	3.3
Peas	3.8	363	28.1	1.3	60.6	3.1
Diced Potato/Gravy	2.1	368	7.3	3.8	76.5	10.3
Potatoes w/Parsley	1.9	368	7.1	3.9	76.8	10.3
Diced Potatoes (plain)	1.9	368	7.1	3.9	76.8	10.3
Mashed Potatoes	5.5	378	7.5	8.0	72.1	7.0
Sweet Potatoes	2.4	382	2.9	0.6	92.4	1.7
Tomatoes	3.3	278	14.4	3.3	68.9	10.0
Wax Beans/Cream Sauce	1.8	481	13.2	25.4	50.0	9.6
Carrots in Cream Sauce	0.9	503	11.9	27.1	52.8	7.3

Table III (continued)

COMMERCIALLY PRODUCED MEAT COMBINATION ITEMS
(per 100 gms of product)

Date	Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.	NACl gms.
3/62	Bacon (A)	4.42	444	47.63	14.55	30.59	2.31	1.72
6/62	Bacon (B)	4.39	446	39.12	19.03	29.60	7.86	5.60
3/62	Beef Hash	3.41	400	49.25	8.25	32.15	6.94	3.97
6/62	Beef Hash	3.48	394	47.09	8.19	33.08	8.16	3.14
5/62	Beef Pot Roast	2.78	449	64.81	17.05	9.11	6.25	4.16
10/62	Beef Pot Roast	1.79	437	68.9	12.83	9.41	7.07	1.59
5/62	Beef/Veg.	2.86	397	46.70	11.90	30.69	7.85	5.25
10/62	Beef/Veg.	2.04	398	51.73	7.8	30.32	8.11	2.01
5/62	Chicken/Gravy	2.40	379	66.28	3.87	19.83	7.62	5.42
10/62	Chicken/Gravy	1.60	386	67.15	4.42	19.56	7.27	3.64
5/62	Fish Creole	3.10	445	36.50	16.6	37.34	6.55	3.65
3/62	Veal	6.47	392	49.03	9.96	26.55	7.99	5.19

Table III (continued)

NUTRITIVE VALUES OF MEAT COMBINATION
ITEMS PRODUCED IN-HOUSE
(per 100 gms of product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.	NaCl gms.
Bacon	2.58	422	34.22	13.59	40.63	8.98	6.62
Beef Hash	2.33	421	41.56	11.72	37.43	6.96	3.89
Beef Pot Roast	1.00	450	69.44	15.51	8.27	5.78	3.81
Beef/Gravy	0.74	447	74.36	14.48	4.90	5.52	4.10
Beef/Vegetables	1.91	419	52.10	10.74	28.58	6.67	6.66
Chicken Stew w/Vegetables	1.65	370	47.63	2.18	39.99	8.55	6.64
Chicken Rice	1.44	371	75.18	2.82	11.22	9.34	7.92
Fish Creole	1.53	449	31.92	15.79	44.68	6.08	2.59
Spaghetti in Tomato Sauce	1.75	391	11.78	6.72	70.91	8.84	5.02

Table III (continued)

NUTRITIVE VALUES OF MEAT COMBINATION
ITEMS PRODUCED IN-HOUSE
(per 100 gms. of product)

Sample Identification	Water Pct.	Energy Cal.	Protein gm.	Fat gm.	Carbohydrate gm.	Ash gm.	NaCl gms.
Chicken/Gravy	1.64	379	71.72	2.58	17.26	6.80	5.18
Meat Balls/Gravy	0.93	582	48.66	40.43	5.9	4.08	2.68
Noodles/M. Sauce (Original)	1.35	376	15.16	19.14	57.29	7.06	6.40
Noodles/M. Sauce (Reformulated)	2.81	376	44.80	8.14	30.84	13.41	11.51
Swiss Steak	1.02	457	63.48	17.82	10.99	6.69	5.26
Turkey/Gravy	1.96	387	73.39	4.72	12.63	7.30	4.73
Veal	1.40	413	50.15	10.53	29.53	8.39	5.27

Table IV

Formulation of Foods

Chicken and Gravy

	Percent by Weight
Chicken, cooked, ½ inch cubes	45.80
Water	47.10
Gravy mix*	7.10
*Gravy mix	
Soup and gravy base, chicken flavored	45.5
Milo starch	31.00
Nonfat milk solids	21.00
Minced onions, white, dehydrated	1.50
Celery, dried	0.80
Pepper, black, ground	0.20

Veal with Barbecue Sauce

Veal, cooked, ½ inch cubes	42.90
Water	41.10
Gravy mix*	16.00
*Gravy mix	
Lard flakes	3.53
Oleo stock	14.10
Applesauce, dehydrated	15.29
Worcestershire sauce	4.70
Onion powder, white	13.00
Tomato flakes dehydrated	17.64
Salt	8.82
Brown sugar	7.05
Grapefruit juice powder	5.90
Beef extract	2.35
Vinegar dry	2.35
Vegetable protein, hydrolyzed	1.76
Paprika	1.17
Yeast extract	1.17
Garlic powder	0.59
Celery seasoning	0.23
Pepper, black, ground	0.35

Table IV (continued)

	Percent by Weight
Bacon	
Canadian bacon, ¼ inch cubes	24.48
Applesauce canned	37.50
White sauce*	12.50
*Accent International "Sauce Quick"	
Beef Hash	
Beef, cooked, ground	24.48
Potatoes, cooked, diced, dehydrated	36.62
Monosodium glutamate	0.34
Salt	0.34
Broth beef deluted, ½:½ water	36.28
Hash gravy*	
*Hash gravy	
Clear gel, instant	29.00
Caramel color powder	3.00
Onion powder	1.00
Salt	18.00
Monosodium glutamate	0.83
Pepper, ground, white	0.25
Vegetable protein, hydrolyzed	1.00
Oleo stock	14.00
Lard flakes	3.00
Vinegar, dry	1.50
Milk, nonfat, dry	28.00
Celery, ground	0.30
Beef with Vegetables	
Beef, cooked, ¼ inch cubes	27.86
Potatoes, cooked, ¼ inch cubes	12.44
Peas, cooked	8.65
Carrots, cooked, ¼ inch cubes	12.44
Beef broth deluted ½:½ water	34.83
Gravy mix*	3.78

Table IV (continued)

	Percent by Weight
*Gravy mix	
Clear gel, instant	40.00
Soup and gravy base, beef	50.00
Vegetable fat, hydrogenated	4.00
Vegetable protein, hydrolyzed	5.50
Caramel color powder	0.50
Beef Pot Roast	
Beef, cooked, ¼ inch cubes	49.50
Beef broth diluted ½:½ water	43.75
Gravy mix*	4.25
*Gravy mix	
Clear gel, instant	40.00
Soup and gravy base, beef	50.00
Vegetable fat, hydrogenated	4.00
Vegetable protein, hydrolyzed	5.50
Caramel color powder	0.50
Spaghetti with Meat Sauce	
Beef, ground, cooked	28.00
Noodles, cooked, angel hair	24.70
Water	28.60
Meat juice, filtered, chilled	15.50
Brown gravy*	3.20
*Brown gravy	
Starch, pregelatinized waxy maise	39.35
Caramel color powder	1.64
Onion powder	4.92
Salt	31.97
Monosodium glutamate	3.92
Pepper, black, ground	0.50
Oleo stock	17.20
Citric acid	0.50

Table IV (continued)

Fish Creole	Percent by Weight
Fish, haddock, cooked	25.90
Rice, instant, cooked	12.95
Potatoes, cooked, ½ inch cubes	7.77
Tomato paste	5.18
Pimento, sweet, dried	3.23
Vegetable shortening	1.30
White sauce*	5.18
Peas, cooked	9.73
Onion powder	.082
Garlic powder	.009
Salt, non-iodized	.242
Pepper, white, ground	.018
Paprika, ground	.009
Broth fish cooked in	28.40

Chicken Stew	
Chicken, cooked, ½ inch cube	23.60
Potatoes, cooked, ½ inch cube	17.00
Peas, cooked	15.80
Carrots, cooked, ½ inch cube	10.50
Water	27.80
Salt	0.50
Gravy mix*	4.90

*Gravy mix	
Soup and gravy base chicken	21.83
Salt	5.46
Poultry seasoning	0.18
Monosodium glutamate	0.09
Milo starch	36.22
Milk, nonfat dry	36.22

Table IV (continued)

	Percent by Weight
Beef w/gravy	
Beef, cooked, ½ inch cube	68.31
Brown gravy*	4.37
Beef broth (½ broth plus ½ water)	27.32
*Brown gravy	
Pre-gelatinized Waxy Maise Starch	39.34
Caramel Color	1.64
Onion powder	4.92
Salt	31.96
Monosodium glutamate	3.92
Pepper, black, ground	0.50
Oleo stock	17.22
Citric Acid	0.50
Swiss Steak	
Beef, cooked, ½ inch cube	60.61
Swiss Steak gravy*	9.09
Beef broth (½ broth plus ½ water)	30.30
*Swiss Steak gravy	
Pre-gelatinized waxy maise starch	26.00
Powdered cream (Pream)	23.00
Salt	18.00
Oleo stock	14.00
Lard flakes	3.00
Onion chips (browned, dehydrated)	6.55
Caramel Color	3.00
Dry vinegar	1.50
Hydrolyzed vegetable protein	1.00
Minced onion, dehydrated	1.50
Celery seasoning	1.06
Monosodium glutamate	0.83
Paprika	0.30
Black pepper, ground	0.25

Table IV (continued)

Beef w/Mushroom Gravy

	Percent by Weight
Beef, diced, ½ inch precooked	37.4
Mushrooms, ½ inch precooked	12.6
Mushroom gravy*	50.0
*Mushroom Gravy	
Mushroom juice	84.62
Nonfat dry milk	7.69
Pot roast gravy **	7.69
**Pot Roast Gravy	
Waxy maise starch	40.5
Caramel color powder	2.0
Onion powder, white	2.5
Onion chips, brown, dehydrated	5.0
Salt	20.0
Monosodium glutamate	1.5
Black pepper, ground	0.5
Worcestershire sauce	3.5
Hydrolyzed vegetable protein	1.5
Oleo stock	17.5
Lard flakes	4.0
Citric acid	1.0

Chicken and Rice

Chicken, cooked, ½ inch cubes	57.2
Soup and Gravy base chicken	5.7
Hot water to rehydrate soup and gravy base	20.3
Waxy maize starch	1.4
Hot water to rehydrate starch	15.5

After dehydrating chicken and gravy, mix 20 grams of dehydrated chicken and gravy with 12 grams of Minute Rice.

Table IV (continued)

	Percent by Weight
Turkey w/Gravy	
Turkey, white meat, ½ inch cubes, precooked	45.8
Gravy mix*	7.1
Turkey broth, ½ water, ½ broth	47.1
*Gravy Mix	
Soup and gravy mix base chicken	45.5
Milo starch	31.0
Nonfat milk solids	21.0
Onions, diced, white, dehydrated	1.5
Celery, diced, dehydrated	0.8
Black pepper ground	0.2
Carrots w/Sauce	
Carrots, ½ inch cubes cooked	41.2
White sauce "Sauce Quick" *	9.8
Water	49.0
Meat Ball w/Gravy	
Beef, top or bottom round ground	61.28
Beef fat	12.29
Water	20.44
Corn Meal yellow	2.04
Salt non-iodized	0.77
Pepper, white, ground	0.08
Onion minced, dehydrated	0.56
Vegetable shortening	2.54
Meat Ball	91.76
Meat Ball Gravy*	8.24

* Accent International

Table IV (continued)

*Gravy	Percent by Weight
Instant clear gel	38.10
Caramel color powder	1.90
Salt	18.10
Monosodium glutamate	1.59
Pepper, black, ground	0.17
Oleo stock	16.24
Lard flakes	3.80
Sugar	20.00

Spaghetti in Tomato Sauce

Commerically canned (14½ oz) heat and eat Spaghetti in Tomato Sauce. Only modification was spaghetti was reduced in size to approximately ½ inch by mixing at slow speed in a mixer.

Chicken Noodle Soup

Soup and gravy base chicken	50.0
Noodles fine "Slabys'"	50.0

Chicken Rice Soup

Soup and gravy base chicken	50.0
Rice instant precooked	50.00

Beef-Rice Soup

Soup and Gravy base, beef	37.5
Rice, instant precooked	62.5

Table IV (continued)

	Percent by Weight
Tomato Soup	
Tomato flakes	50.00
Salt	11.67
Monosodium glutamate	6.65
Instant clear gel	6.65
Pepper, black, ground	0.16
Onion powder	3.32
Garlic powder	2.40
Potatoes, dehydrated granules	8.32
Sugar	10.00
Citric acid	0.83
Mushroom Soup	
Mushroom soup, dehydrated, Liptons	69.5
Non-fat milk dry	30.5
Noodles Seasoned	
Macaroni, instant	61.09
Chicken, cooked, dehydrated, powdered	15.26
Gravy mix*	19.84
Shortening, hydrogenated, 100AOM	3.8
*Gravy mix	
Soup and gravy base, chicken flavored	45.5
Milo starch	31.0
Nonfat dry milk	21.0
Minced onions, white, dehydrated	1.5
Celery, diced, dehydrated	0.8
Pepper, black, ground	0.2
Rice with Gravy	
Rice, instant	63.49
Chicken, cooked, dehydrated, powdered	15.87
Gravy mix*	20.64

*Same as gravy mix used in Noodles Seasoned.

Table IV (continued)

Spanish Rice	Percent by Weight
Rice, instant	71.12
Spanish rice seasoning*	23.53
Shortening, hydrogenated 100AOM *	5.35
*Seasoning	
Tomato flakes	55.0
Onions, dehydrated	15.0
Salt	12.0
Sugar	9.0
Green pepper, dehydrated	9.0
Whole Wheat Cereal	
Instant Ralston	51.52
Nonfat dry milk	28.24
Sugar	13.29
Salt	0.33
Shortening, hydrogenated 100 AOM	6.62
Oatmeal Cereal	
Instant Oatmeal (Maypo)	51.33
Nonfat dry milk	28.15
Sugar	13.24
Shortening, hydrogenated, 100 AOM	6.62
Salt	0.33
Imitation maplenut flavor	0.33
Cream of Rice	
Cream of Rice (Grocery Store Product Co.)	67.67
Nonfat dry milk	15.04
Sugar	9.02
Salt	0.75
Shortening, hydrogenated, 100 AOM	7.52

* Active Oxygen Method

Table IV (continued)

	Percent by Weight
Cream of Wheat	
Cream of wheat (Cream of Wheat Corp.)	51.50
Nonfat dry milk	28.24
Salt	0.33
Sugar	13.29
Shortening, hydrogenated, 100 AOM	6.64
Oat Cereal (A)	
All Star (Kellogg)	61.54
Nonfat dry milk	34.61
Sugar	3.85
Oat Cereal (B)	
Frosty "O" (General Mills)	64.29
Nonfat dry milk	32.14
Sugar	3.57
Corn Cereal	
Corn Chex (Ralston Purina)	56.82
Nonfat dry milk	20.46
Sugar	22.72
Corn Flakes Sweetened	
Corn flakes sugar coated (Kellogg)	81.63
Nonfat dry milk	18.37

Table V T-4 Medium

Source of Nutrient Element	Conc. of Stock Sol. gm/L	ml of Stock/L of Medium	gm/L of Medium
$(NH_2)_2CO$			0.4
KH_2PO_4			2.5
$MgSO_4 \cdot 7H_2O$			5.0
$CaCl_2 \cdot 2H_2O$			0.0294
NaCl			2.0
$FeCl_3 \cdot 6H_2O$	2.416	1	
Trace #1 Elements			
H_3BO_3	2.858	1	
$CuSO_4 \cdot 5H_2O$	0.079	1	
$MnCl_2 \cdot 4H_2O$	1.801	1	
$ZnSO_4 \cdot 7H_2O$	0.2200	1	
MoO_3	0.0190	1	
Trace #2 Solution Containing		10	
$KCr(SO_4)_2 \cdot 12H_2O$	0.0098		
$NH_4VO_3 \cdot 2H_2O$	0.00179		
$NaWO_4 \cdot 2H_2O$	0.00448		
$KTi(C_2O_4)_2 \cdot 2H_2O$	0.00740		
$CO(NO_3)_2 \cdot 6H_2O$	0.00495		
KOH	28.075		
EDTA	50		

Potassium hydroxide and acetic acid used for pH adjustments.

The main nutrient elements are in the same proportion as those recommended by Dean Burk to Electric Boat. However, a more complete trace nutrient formula than that recommended by Dean Burk has been used.

Table VI T-6 Medium

Source of Nutrient Element	Conc. of Stock Sol. gm/L	ml of Stock/L of Medium	gm/L of Medium
$(NH_2)_2CO$			2.71
KH_2PO_4			3.055
$MgSO_4 \cdot 7H_2O$			5.6655
$CaCl_2 \cdot 2H_2O$			0.03358
K_2SO_4			0.1430
NaCl			2.0
$FeCl_3 \cdot 6H_2O$	2.416	7.875	
Trace #1 Elements			
H_3BO_3	2.858	2	
$CuSO_4 \cdot 5H_2O$	0.079	2	
$MnCl_2 \cdot 4H_2O$	1.801	2	
$ZnSO_4 \cdot 7H_2O$	0.2200	2	
MoO_3	0.0190	2	
Trace #2 Solution containing		20	
$KCr(SO_4)_2 \cdot 12H_2O$	0.0098		
$NH_4VO_3 \cdot 2H_2O$	0.0023		
$NaWO_4 \cdot 2H_2O$	0.00179		
$NiSO_4 \cdot 6H_2O$	0.00448		
$KTi(C_2O_4)_2 \cdot 2H_2O$	0.00740		
$Co(NO_3)_2 \cdot 6H_2O$	0.00495		
	28.075		
KOH	50		
EDTA			

Potassium hydroxide and acetic acid used for pH adjustments.

Table VII Effects of Processing Methods Upon Loss of Protein Content and Loss of Color of Chlorella 71105.

Treatment of Algae	Original Sample (gm)	Total Dry Weight Approx. Loss (%)	Protein (Nx6.75) (%)	Color-1931 C.I.E. Values *** of Freeze-Dehydrated Product Y	X	Y	Munsell Color Notation
1. Raw**	-	0	55.5	13.47	0.4171	0.5434	3.5 GY 4.22/9
4. Methanol Extracted	39	31	81.0	63.32	0.3159	0.3569	9 GY 8.23/2.75
5. Methanol Extracted 3% H_2O_2	39	36	74.3	67.20	0.2973	0.3363	6.9 G 8.44/2.4
2. Ethanol Extracted 1 hour	20	35	89*	17.57	0.3310	0.4642	8.0 GY 4.75/7
3. Ethanol Extracted 24 hour	20	40		34.22	0.3579	0.3710	5Y 6.35/3

* For 6 hour extraction

** Algae treated by preparing a roux would have values close to raw algae

*** Commission Internationale de l'Eclaerage

Table VIII

Protein and Amino Acid Analysis of Raw and Processed Algae
(mg amino acid per gm of protein)

Protein or Amino Acid	Raw	Methanol Extracted	Methanol Extracted H_2O_2 Bleached	Ethanol Extracted
Lysine	62.72	57.31	50.13	63.46
Histidine	13.16	15.13	7.63	17.93
Ammonia	33.01	29.14	30.20	30.52
Arginine	65.64	74.56	65.75	68.55
*	trace	trace	considerable	trace
Cysteic Acid	trace	some	trace	trace
Methionite Sulfoxides	some	trace	trace	trace
Aspartic & Hydroxyproline	102.17	109.27	113.04	91.71
*	-	trace	considerable	-
Threonine	34.44	39.36	49.56	43.95
Serine	31.79	26.70	34.42	32.00
Glutamic Acid	140.71	119.96	134.32	122.53
Proline	53.51	46.96	48.79	50.36
Glycine	73.68	71.76	71.47	72.32
Alanine	115.90	106.83	106.87	107.99
Valine	69.83	78.22	79.13	82.55
Methionine	11.97	16.49	11.18	15.44
*	trace	considerable	trace	trace
Isoleucine	42.75	43.82	44.39	43.69
Leucine	107.23	120.17	112.47	108.17
Tyrosine	29.18	31.53	28.14	31.62
Phenylalanine	53.43	56.17	57.91	49.31
% Protein dry wt. algae	55.5	81.0	74.3	89.0

*Small peaks not identified or calculated.

Table IX Relative Merits of Debitterizing and Decolorization Methods

Process	Taste	Color	Equipment Required	Chemicals Regd.	Time Regd. For Treatment	Approx. Loss of Product
Raw	Very bitter	Dark Green	None	None	None	None
Methanol	Somewhat bitter	White	Soxhlet & Drying (Bleaching Vessel)	Non Edible	Min.* 12	35%
Ethanol	Not bitter	Light Green	Soxhlet & Drying	Non Edible	Min.* 8 hr.	35%
Roux	Not bitter	Dark Green	Kitchen equipment	Edible	1/2 hr.	None

*Time includes washing algae, centrifuging, Soxhlet extraction, bleaching, and drying.

Table X, Algae Recipes

1. **Cream of algae onion soup. - Excellent**

Ingredients		Method
Algae	1/2 oz.	1. Prepare roux
Butter	2 oz.	2. Add flour, blend well
Flour, wheat	1 oz.	3. Add onions, blend and cook 2 minutes
Soup and Gravy		
Base (Chix)	1 oz.	4. Add soup and gravy base and milk stirring constantly
Onions	1 oz.	
Milk whole	4 c	5. Heat to 190 degrees F and cook 5 minutes

2. Algae Potato Soup - Good

Ingredients		Method
Algae	3 oz.	1. Prepare roux
Butter	1 oz.	2. Hold onion and garlic, cook 1 minute
Onions, minced dehy.	1 oz.	3. Stir in flour, blend well
Flour, wheat, hard	1 1/2 tsp.	
Soup and gravy base	1 tsp.	4. Add milk and soup and gravy base stirring constantly. Simmer 3 to 5 minutes.
Milk	2 c	
Potato granules dehy.	3.2 oz.	
Salt	1 tsp	
Pepper	1/8 tsp	
Garlic	1 small button	

Table X

3. Mashed Potatoes - Excellent

Ingredients	
Algae	4 oz.
Butter	1 oz.
Water	1 3/4 c
Milk, whole	3/4 c
Salt	5 gm.
Pepper	1/16 tsp.
Potato granules	4 oz.

Method

1. Prepare roux
2. Bring water to a boil. Add milk, heat to 170 degrees f.
3. Add potatoes to hot liquid while stirring.
4. Add algae butter to potatoes. Whip with high speed mixer 1 min.

4. Beef Burger - Excellent

Ingredients	
Algae	42 gm
Butter	9 gm
Ground beef	113 gm
Onion, dehyd.	2 gm
Salt	1 tsp
Black Pepper	1/2 tsp

Method

1. Prepare roux
2. Mix ingredients
3. Shape into patties.
4. Grill on lightly greased grill at 350 degrees F until well done or shape into small meat balls and fry in deep fat 400 degrees F until well done.

Table X

5. Fruit Bars - Very Good

Ingredients		Methods
Algae	31.5 gm	1. Prepare roux
Butter	3.1 gm	2. Blend pineapple and fruit cocktail in Waring blender
Pineapple, freeze-dehydrated	100 gm	3. Mix in roux and dextrine
Fruit cocktail, powdered freeze-dehyd.	100 gm	4. Roll and cut into bars 1/4 in. thick x 1/2 inch wide x 2 in. long
Dextrine	100 gm	5. Place on wax paper. Allow to set until moisture and aroma are thoroughly equalized.

6. Cocoa Beverage - Poor

Ingredients		Method
Algae	7.9 gm	1. Prepare roux
Butter	2. gms	2. Mix roux, and cocoa beverage
Cocoa Beverage	7 oz.	3. Heat to 160 degrees F.

Table X

7. Pancakes - Fair

Ingredients		Method
Algae	60 gm	1. Prepare roux
Butter	27 gm	2. Mix and sift dry ingredients.
Baking Soda	1/2 tsp	3. Beat egg and add roux. Beat until well blended.
Egg	1	4. Add dry ingredients blending well
Milk, non fat dry	1/4 c	5. Cook on lightly battered grill at 300 degrees F until brown on both sides
Salt	1/2 tsp	
Flour, soft wheat	1/2 c	
Sugar	1 tb	

8. Oatmeal - Fair

Ingredients		Method
*Algae	21 gm	1. Prepare roux
*Corn Oil	6 gm	2. Mix roux with water bring to boil
Oatmeal, instant	56 gm	3. Add oatmeal, milk, and salt while stirring
Milk, non fat dry	15 gm	4. Bring to a boil
Water, hot	11 oz	

*approx. amounts

APPENDIX

DEVELOPMENT OF FOOD ITEMS TO MEET AIR FORCE REQUIREMENTS FOR SPACE TRAVEL

I. Precooked-Dehydrated Foods

A. Specific Requirements

1. A variety of acceptable and nutritious prototype precooked-dehydrated foods suitable for consumption during a 14-day aerospace mission shall be developed. These will include items in the following food classes: - Beverages, cereals, desserts, fruits, fruit juices, meats and meat substitutes, soups and vegetables.

2. Foods will be stored and consumed by astronauts in a space vehicle where the temperature ranges from 50° to 80°F; altitude will approximate a pressure equivalent to 25,000 feet; relative humidity will range from 30% to 50%; atmosphere will be approximately 100% oxygen; an accelerative load factor of 8 "G" will act in any direction; and weightlessness will prevail.

B. Essential Characteristics

1. Foods which are to be served hot shall be capable of being reconstituted within 15 minutes in water whose temperature does not exceed 162° to 165°F. Items not eaten hot, such as applesauce or milk, shall be capable of being reconstituted in water of ambient capsule temperature.

2. When reconstituted, foods shall be in a liquid, semisolid, minced, or diced form so as to permit consumption through a collapsible squeeze tube. The desirable size for minced or diced food is a 1/4 to 3/8-inch cube.

3. Foods shall be packaged in individual servings. They will be stored, reconstituted, and eaten from a feeding container assembly which will be furnished by the Air Force.

4. When reconstituted, foods shall closely resemble the color, flavor and texture of freshly prepared.

5. Acceptibility of prototype foods shall be measured in terms of a rating of 6.0 or above on a 9.0 Hedonic scale of like-dislike when served to taste-test panel personnel at the Quartermaster Food and Container Institute.

6. Foods shall be non-thirst provoking, easily digested, and non-gas forming.

C. Desirable Characteristics

1. The nutritive value of precooked-dehydrated foods should be as high as is practical, yet consistent with acceptability and other limiting characteristics.

2. Foods shall be stable for 6 months at a constant temperature of 100°F and intended for 2 years at ordinary warehouse storage (70°F).

II. Bite-Size Solids

A. Specific Requirements

A variety of prototype bite-size solids with dispensing device suitable for consumption in an aerospace vehicle shall be developed. The texture and chewing qualities of these foods shall be such as to enhance the acceptability of meals comprised chiefly of liquids, semisolids, and minced foods packaged in tubes. A variety of 15 dessert items to be consumed with meals or as between-meal snacks are desired. These shall take the form of cake and combinations of raisins, nuts and candy. In addition, the feasibility of bite-size pieces of beef, ham, and freeze dried celery, carrot, corn, pineapple, peaches and grapes should be investigated. These foods will be stored and consumed in the environment outlined in paragraph IA2 above.

B. Essential Characteristics

1. Foods shall be in pieces no greater than a 3/4-inch cube. If edible coating is necessary, materials used shall be digestible and shall protect foods from exchange of flavors, dehydration, bacterial spoilage and crumbling. Coatings shall carry the minimum possible "off" flavors, odor or color. For example, coated pieces of white cake should look and taste like a palatable and acceptable food. Similar connotations apply to odor and color. The ratio of food to coating shall be as high as is practicable as close to as possible to 90% food content to 10% coating.

2. Foods shall be stable when maintained under refrigerated storage (35° ± 2°F) for a period of 6 months. They shall remain stable without refrigeration under conditions described in IA2 above for at least 3 days.

3. Acceptability of prototype bite-size solids shall be measured in terms of receipt of a rating of 6.0 or above on a 9.0 Hedonic scale when served to taste-test panel personnel at the Quartermaster Food and Container Institute.

4. Foods will be packaged to permit easy access to a single piece of food at a time with gloved hand. Containers shall be fabricated of lightweight aluminum or other suitable approved material. They shall be rectangular in shape for economy of storage space and convenience in

handling. Containers shall be designed to permit easy opening. Each dispensing unit will provide up to 6-8 ounces of edible food.

C. Desirable Characteristics

Nutritive value shall be as high as is practicable, yet consistent with acceptability and other limiting characteristics.

III. Tube Foods

A. Specific Requirements

A variety of prototype liquids, semisolids, and minced foods packaged in prototype lightweight collapsible tubes made of plastic, thin metal, or laminates of plastic and metal shall be developed. A variety of soups, fruit desserts, fruit or vegetable juices and milk drinks, shall be developed to provide food for 3 to 4 day mission.

B. Essential Characteristics

1. Food, in average servings, shall be packaged in collapsible containers with pontube and expelling device. This feeding container assembly shall be a single unit item. It will be designed to delivery as close as possible to 95% or more of the contents of each tube.

2. Foods must be capable of storage without refrigeration for 6 months.

3. Foods must be acceptable without heating and should flow easily at temperatures ranging from 50° to 80°F.

4. Prototypes must receive a rating of 5.5 or above on a 9.0 Hedonic scale of like-dislike when served to taste-test personnel at the Quartermaster Food and Container Institute, to be considered acceptable.

C. Desirable Characteristics

The nutritive value of these foods must be as high as is practical yet consistent with acceptability and other limiting characteristics.

IV. Algae

A. Investigations shall be initiated to study the food technology of the Sorokin strain of Chlorella. Emphasis should be placed on modifying flavor, taste and color so that algal suspensions can be used as food extenders of additives to enhance nutritive value of precooked-dehydrated foods, beverages, or if feasible, other foods.